IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of

David Abraham et al.

Serial No.: 10/680,260 **Group Art Unit**: 2814

Filed: October 8, 2003 **Examiner**: Mai, Anh D.

For: METHOD AND SYSTEM FOR PATTERNING OF MAGNETIC THIN FILMS USING CHEMICAL TRANSFORMATION

Honorable Commissioner of Patents
Alexandria, VA 22313-1450

DECLARATION UNDER 37 C.F.R. §1.131

Sir:

We, David Abraham and Eugene J. O'Sullivan, do hereby state that:

1) We are the inventors of the above-identified application.

2) The method and system for patterning of magnetic thin films using chemical transformation was invented by us earlier than March 29, 2002 (the earliest effective prior art date of the applied prior art references), as shown in the enclosed memorandum (Exhibits 1-3). The effective date of the memorandum (Exhibits 1-3) is earlier than March 29, 2002 and the date thereof has been redacted.

3) The above clearly evidences a completion (reduction to practice) of the invention in the United States before the filing dates of the applied prior art references, Kamata, Grynkewich and Klemmer, which are March 29, 2002, April 22, 2003 and October 21, 2002, respectively.

4) The facts in the above, 3) clearly show a completion date (reduction to practice) of the invention in the U.S. prior to March 29, 2002 (the earliest filing date of the applied prior art references).

We hereby declare that all statements made here of our own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application for any patent issued thereon.

Further declarants sayeth not.

Date: _____ _____
David Abraham

Date: _____ _____
Eugene J. O'Sullivan

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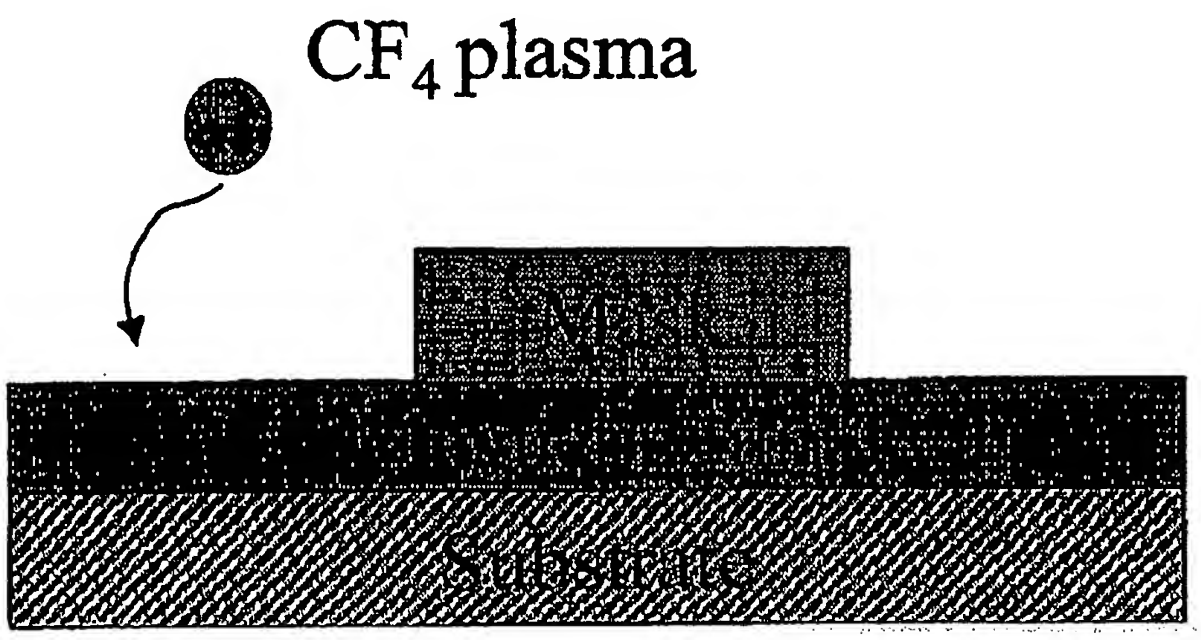
using the invention.
Patterning of thin magnetic films for application in various sensors and devices such as thin-film disk drive read heads and magnetic memory elements has relied on removal of material by reactive ion etching, ion milling and other substractive techniques. These methods use physical removal of material in order to delineate a region both magnetically and electrically. Typically, the region to be patterned is of micron or submicron dimension, and often sensitivity to edge roughness, profile and redeposited material determines the quality of the final product. More recently, experiments by Folks et al. have used ion beams to pattern (by damage and by implantation) without removal of material. (Patent approaching filing soon according to the authors in IBM Almaden).

In the case of magnetic memory (MRAM) structures, patterning of the tunneling junction device as discussed above is of utmost importance in achieving final success. Mainly, the failure of the final product is due to non-uniformity of magnetic switching properties in the potentially millions of junctions on a memory chip. This variability is traced to many different factors, but one of the most important is in the patterning process. Gross differences in shape lead to a variation in switching field. Also, edge roughness is known to cause variation due to edge pinning of magnetization. Finally, magnetic hardening of the edges due to oxidation, edge thinning, and magnetic effects due to redeposited material all influence magnetic performance. In all of the patterning methods in which removal of material is used (ion milling and RIE for example) the edges of the patterned area are compromised in at least one of these ways. Ion-beam patterning (as opposed to ion milling) offers significant promise for improved performance but remains unproven.

We propose an alternative method for patterning of magnetic thin films which uses chemical transformation of the undesirable part of the film to transform it to be non-magnetic. The preferred realization of this technique would be to first use photolithographic techniques to provide a mask on top of the magnetic sample in the usual way. This mask would lie on top of the region to be preserved, and would be made in the usual fashion either relying on the photoresist as a mask material and/or a hard mask patterned layer consisting of diamond-like carbon, TiN or similar materials.



Conversion of the magnetic film is achieved by a gentle RIE sputter in a plasma of CF4. At pressures used we don't see erosion of the material, but rather conversion of the NiFe film to a flourine-containing film. The properties of this flourinated layer of interest here are a) magnetically inactive (i.e. non-ferromagnetic) and b) electrically insulating. Subsequent processing can now proceed as normal to produce a functioning magnetic device. An example of this structure is shown in the next figure:

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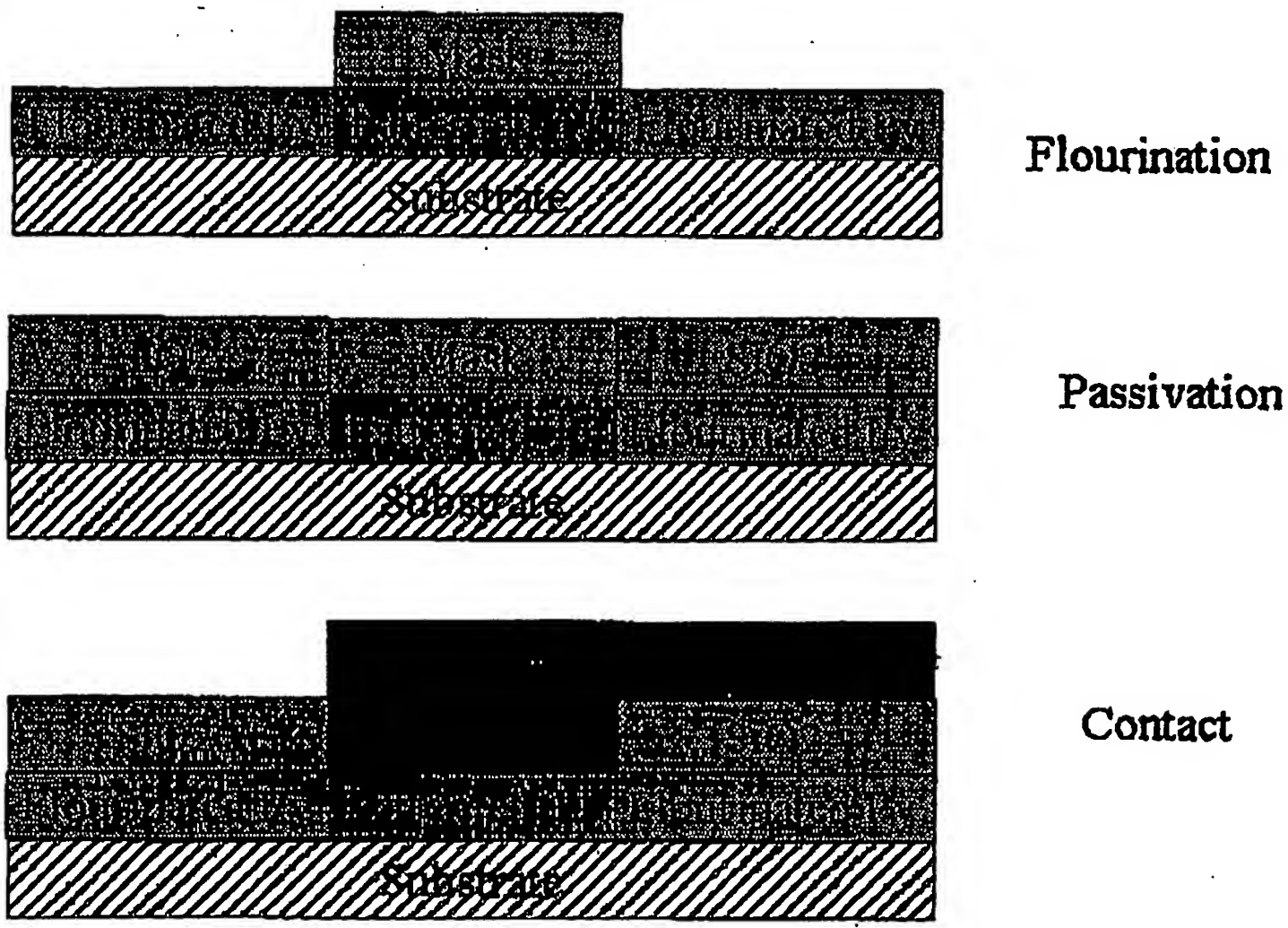

Example 1. A substrate comprising Si I SiO_2 I Ta (50 A) I $Ni_{81}Fe_{19}$ I Ta (50) was etched in a Plasmalab RIE tool for 3.0 min at 150 W power, a DC bias of ca. 300 V, 10 mT pressure, and 20 sccm SF_6 exhibited a change in magnetic moment from an initial value of 1.29×10^{-3} to 5.71×10^{-4} after the run. After a total of 9 min of exposure to the plasma, the moment had decreased to 4.54×10^{-4} (units ??).

Oxygen present in a CF_4 or SF_6 plasmas reacts with the carbon and sulfur, respectively, thereby increasing the concentration of fluorine atoms in the plasma. This results in a more active plasma, which can yield higher etch rates for materials such as SiO_2. It was decided to investigate the effect of O_2 addition to fluorine-containing gases on the rate of conversion of permalloy to a fluoride compound in this work.

Example 2. A substrate comprising Si I SiO_2 I Ta (50 A) I $Ni_{81}Fe_{19}$ I Ta (50) was continously etched in a Plasmalab RIE tool for 4.0 min at 150 W power, a DC bias of ca. 280 V, 10 mT pressure, a gas mixture of 15 sccm SF_6 + 5 sccm O_2 exhibited a moment reduction from 8.51×10^{-4} emu down to 1.73×10^{-4} emu.

Example 3. A substrate comprising Si I SiO_2 I Ta (50 A) I $Ni_{81}Fe_{19}$ I Ta (50) was etched for two periods of 2.0 each in a Plasmalab RIE tool for 4.0 min at 150 W power, a DC bias of ca. 280 V, 10 mT pressure, a gas mixture of 15 sccm SF_6 + 5 sccm O_2 exhibited a moment reduction from 8.8×10^{-4} emu down to 2.4×10^{-4} emu. The smaller decrease in moment here compared to the previous example may be due to a lower level of heating in this run due to the cooling period of 5 min employed between the two 2 min runs.

Example 4. A substrate comprising Si I SiO_2 I Ta (50 A) I $Ni_{81}Fe_{19}$ I Ta (50) was continously etched in a Plasmalab RIE tool for 4.0 min at 150 W power, a DC bias of ca. 280 V, 10 mT pressure, a gas mixture of 12.5 sccm CF_4 + 7.5 sccm O_2 exhibited a moment reduction from 7.4×10^{-4} emu down to 2.08×10^{-4} emu.

Example 5. A substrate comprising Si I SiO_2 I Ta (50 A) I $Ni_{81}Fe_{19}$ I Ta (50) was continously etched in a

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Plasmalab RIE tool for 4.0 min at 150 W power, a DC bias of ca. 310 V, 10 mT pressure, a gas mixture of 5 sccm SF_6 + 15 sccm O_2 exhibited a moment reduction from 8.76 x 10^{-4} emu down to 5.6 x 10^{-4} emu. Here the reduction in moment is relatively low, apparently due to the competing process of passivation by oxygen of the surface of the permalloy layer

Example 6. A substrate comprising Si I SiO_2 I Ta (50 A) I $Ni_{81}Fe_{19}$ I Ta (50) I DLC (1000 A) I photoresist (6,400A) was employed. The photoresist was patterned using ebeam lithography to give features that were ca. 0.28 microns wide and 1.4 microns long. The diamond like carbon (DLC) hardmask was patterned using an O_2 RIE step. The permalloy layer was then subjected to an SF6/O2 plasma using the same conditions as in Example 2. The material exhibit a magnetic hysteresis loop as shown in the following figure, indicating from the magnitude of the moment and the relatively large switching field that magnetic patterning on a sub-micron scale had been achieved. Further, electrical measurements showed that the sample was insulating, an expected result given that the unprotected permalloy film was converted to a flourinated state as discussed above.

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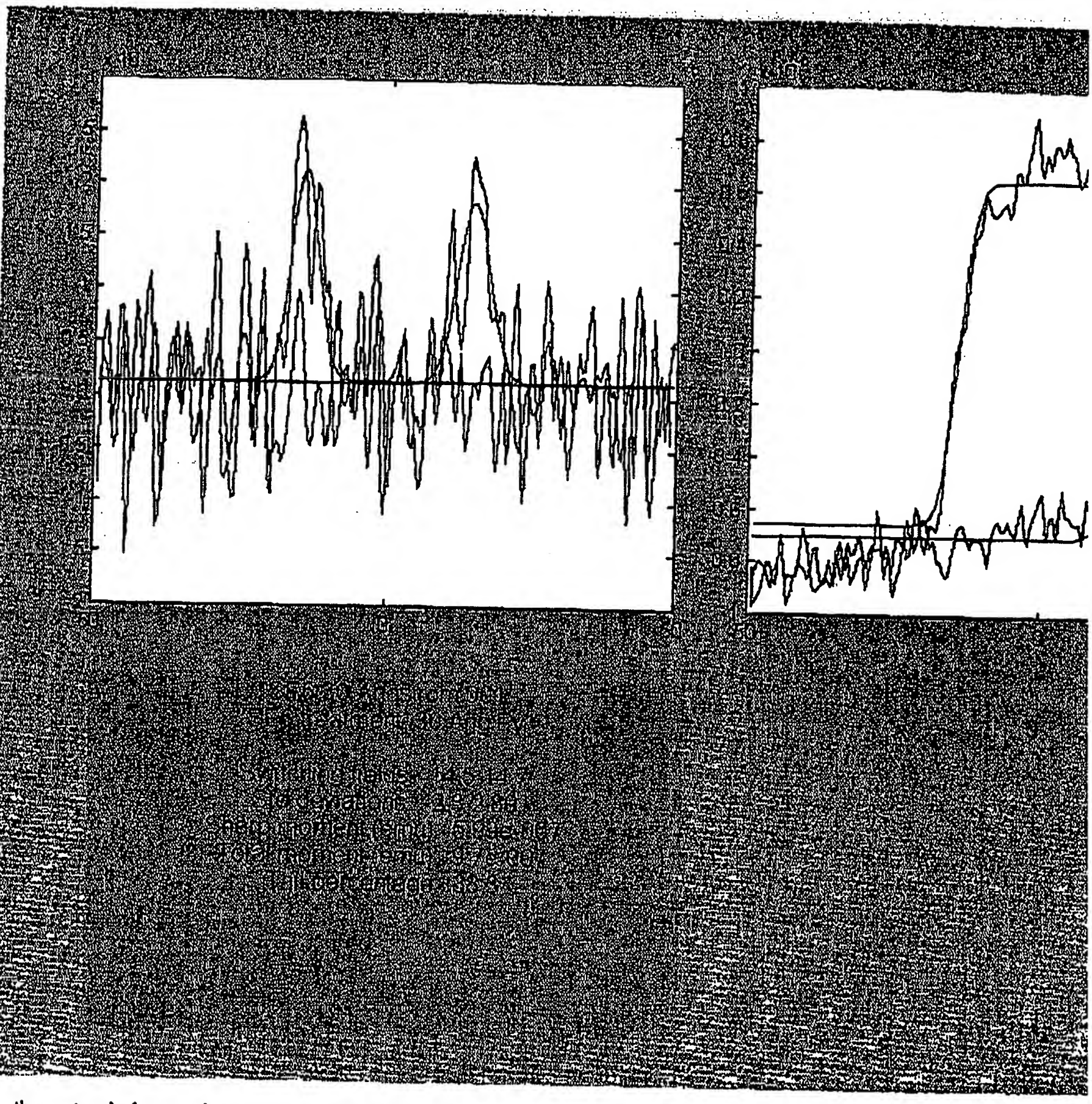

Further, atomic force microscope images show that the surface (aside from remnant hard mask material) is flat, so that patterning does not involve actual removal of material, but rather conversion from the pristine permalloy to an insulating and non-magnetic material.

2. How does the invention solve the problem or achieve an advantage,(a description of "the invention", including figures inline as appropriate)?
This invention is a significant improvement in current processing methods due to the following considerations:

1. There is no exposure of the edges of the junction to oxygen.

2. The edge is more sharply delineated here than in the case of either RIE or ion milling. The sharpness of the edge is most importantly determined by the photoresist line edge roughness, and not by the process itself.
3. There is little topography following patterning so that subsequent fabrication is simplified.

3. If the same advantage or problem has been identified by others (inside/outside IBM), how have those others solved it and does your solution differ and why is it better?
See Folks et al. for implantation method. This technique is quite different in implementation. Some advantages are similar although not yet proven.

4. If the invention is implemented in a product or prototype, include technical details, purpose, disclosure details to others and the date of that implementation.

***Critical Questions (Questions 1-9 must be answered)**

***Question 1**
On what date was the invention workable? 08/22/2000 **Please format the date as MM/DD/YYYY**
(Workable means i.e. when you know that your design will solve the problem)

***Question 2**
Is there any planned or actual publication or disclosure of your invention to anyone outside IBM? ○ Yes ● No

If yes, Enter the name of each publication or patent and the date published below.
Publication/Patent:
Date Published or Issued:

Are you aware of any publications, products or patents that relate to this invention? ○ Yes ● No

If yes, Enter the name of each publication or patent and the date published below.
Publication/Patent:
Date Published or Issued:

***Question 3**
Has the subject matter of the invention or a product incorporating the invention been sold, used internally in manufacturing, announced for sale, or included in a proposal? ○ Yes ● No

Is a sale, use in manufacturing, product announcement, or proposal planned? ○ Yes ● No

If Yes, identify the product if known and indicate the date or planned date of sale, announcements, or proposal and to whom the sale, announcement or proposal has been or will be made.
Product:
Version/Release:
Code Name:
Date:
To Whom:
If more than one, use cut and paste and append as necessary in the field provided.

***Question 4**
Was the subject matter of your invention or a product incorporating your invention used in public, e.g., outside IBM or in the presence of non-IBMers?

If yes, give a date. **Please format the date as MM/DD/YYYY**

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	○ Yes ● No
***Question 5** Have you ever discussed your invention with others not employed at IBM? If yes, identify individuals and date discussed. Fill in the text area with the following information, the names of the individuals, the employer, date discussed, under CDA, and CDA #.	○ Yes ● No
***Question 6** Was the invention, in any way, started or developed under a government contract or project? If Yes, enter the contract number DARPA contract MDA972-99-C-0009 and U.S. Department of Energy, Office of Basic Energy Sciences contract No. DE-AC03-76SF00098.	● Yes ○ No ○ Not sure
***Question 7** Was the invention made in the course of any alliance, joint development or other contract activities? If Yes, enter the following (in English): Name of Alliance, Contractor or Joint Developer Contract ID number Relationship contact name Relationship contact E-mail Relationship contact phone	○ Yes ● No ○ Not Sure
***Question 8** Have you, or any of the other inventors, submitted this same invention disclosure or similar invention disclosure previously? If Yes, please provide disclosure number below:	○ Yes ● No
***Question 9** Are you, or any of the other inventors, aware of any related inventions disclosures submitted by anyone in IBM previously? If Yes, please provide the docket or disclosure number or any other identifying information below:	○ Yes ○ No
Question 10 What type of companies do you expect to compete with inventions of this type? *Check all that apply.*	

MRAM Development Alliance
Invention Disclosure

Created By: Steven Capella **Created On:** 07/12/2001 11:05:34 AM
Last Modified By: Jennifer Da **Last Modified On:** 02/28/2003 01:39:19 PM

*** IBM / Infineon Confidential ***

Required fields are marked with the asterisk (*) and must be filled in to complete the form .

Alliance Sequence Number	14 MDA-_I-0014
Status	Filed By MDA Invention Review Board

Plan Information

Infineon	IBM
Docket #	IBM # YOR820001107
Attorney	Attorney
	Docket #
	Sent to Infineon Date

Supervising Party IBM

Inventors

David W Abraham
Eugene O'Sullivan

Witnessed and understood by :	Witnessed and understood by :
Signature of Witness Date	Signature of Witness Date
Print Name of Witness	Print Name of Witness
Telephone Number	Telephone Number
Company Name/Location	Company Name/Location

***Title of Invention (Short & Descriptive)**

Method for Patterning of Magnetic Thin Films Using Gaseous Transformation

***Problem Solved by this Invention (Summary)**

Provides means of patterning MRAM devices while preserving edges from oxidation and leaving a flat topography.

***List all Written Descriptions of Invention ,Keep for future reference and attach to Disclosure (eg. Described in Engineering Notebook No.__ Pgs.__)**

Attached.

Paste your attachments here if any :

Critical Dates (mm/dd/yy or mm/dd/yyyy)

*Date(s) Invention Conceived:	08/15/2000
*Date(s) Invention Explained to Witness(es):	08/15/2000
Date(s) Prototype(s) of the Invention Constructed:	
Date(s) Prototype(s) of Invention Tested:	

***Planned Use in Products; Use Outside Company,Demonstration, Disclosure, or Publication of the Invention - (Give Dates)**

None

***Description of Invention (Text, Graphics, etc.)**

M01-0014.pdf

IMPORTANT: Information provided by this form may be used to prepare a patent application which will be signed by the inventor(s). Inventors should take great care in accurately completing this form in providing full information concerning prior art. False statements or concealment in obtaining a patent will subject applicant to fine and /or imprisonment (18 USC 1001) and may jeopardize the validity of the patent .

Evaluation Aspects

*What exactly is your claim? Give precisely the difference between your invention (method, structure) and the closest previous work you know of.

See attached pdf.

*What existing solutions are known? Please cite references, patents, etc!

None other than this.

*What are the TECHNICAL pros and cons over existing solutions?

See attached pdf.

*Have you searched for references, patents etc relating to your invention? How was this search performed?

Yes, delphi.

Do you have any other comments regarding this disclosure?

Inventor #1's Signature	Date	Inventor #2's Signature	Date
Inventor #3's Signature	Date	Inventor #4's Signature	Date
Inventor #5's Signature	Date		

Witness #1's Signature	Date	Witness #2's Signature	Date

Disclosure YOR8-2000-1107

Prepared for and/or by an IBM Attorney - IBM Confidential

Created By David W Abraham On 08/25/2000 11:30:47 AM EDT
Last Modified By Enterprise Agentmgr On 05/15/2004 10:06:37 PM EDT
Archived on 05/15/2004

Required fields are marked with the asterisk (*) and must be filled in to complete the form .

Note: This disclosure is a subject invention requiring government contract reporting

***Title of disclosure (in English)**
MDA-0014 Method for patterning of magnetic thin films using gaseous transformation

Summary

Status	Final Decision **(File)**
Docket family	YOR9-2003-0013
* Processing location	Yorktown
* Functional area	(702J) 702J MAGNETOELECTRONICS
Attorney/Patent professional	Casey August/Watson/IBM
IDT team	William J Gallagher/Watson/IBM Casey August/Watson/IBM
Submitted date	11/26/2000 12:59:43 PM EST
* Owning division	RES
Lab	
* Technology code	
Patent value tool (PVT) score	

Inventors with a Blue Pages entry

Inventors: David W Abraham/Watson/IBM, Eugene O'Sullivan/Watson/IBM

Inventor Name	Inventor Serial	Div/Dept	Inventor Phone	Manager Name
> Abraham, David W.	253513	22/UAUA	862-2573	Gallagher, William J.
O'Sullivan, Eugene J.	085229	22/UAUA	862-3997	Gallagher, William J.

> denotes primary contact

Inventors without a Blue Pages entry

IDT Selection

Main Idea

To view the Main Idea of this disclosure, open the "Main Idea" document from the view

*Critical Questions (Questions 1-9 must be answered in English)

*Patent Value Tool (Optional - this may be used by the inventor and attorney to assist with the evaluation)

Final Decision

Post Disclosure Text & Drawings